Comparison of Cyclic Fatigue Resistance of Three Ni-Ti Rotary Files
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Introduction:
Nickel-titanium (NiTi) endodontic instruments have become the most widely used instruments in root canal treatment (RCT).¹ NiTi instruments are characterized by superelasticity and shape memory, but they have an unexpected fracture during instrumentation.² Fracture of NiTi endodontic files during RCT can be due to cyclic fatigue and/or torsional overload.³ ⁴
Cyclic fatigue occurs due to repeated compressive and tensile stresses at the point of maximum flexure. It occurs with no signs of permanent plastic deformation in NiTi instruments, so it is unexpected.⁵ The manufacturers have continuously improved the Ni-Ti endodontic instruments to decrease their cyclic fatigue fracture.⁶ Consequently, there are many recent NiTi instruments in the dental market.⁷ So, it is important to study the cyclic fatigue resistance of these recent NiTi instruments.
This laboratory study was intended to compare the cyclic fatigue resistance of three Ni-Ti rotary files using the time to fracture as an indication for the resistance of the instruments to cyclic fatigue. The null hypothesis was that there would be no significant difference in the cyclic fatigue resistance among the three Ni-Ti tested instruments.

Materials and Methods:
Forty-five different nickel titanium rotary instruments (n = 15) were used in this study. All files were used according to their manufacturers’ instructions.

Cyclic fatigue testing:
A specially designed device was used in this study,

Abstract:
Objective: To compare the cyclic fatigue resistance of three Ni-Ti rotary files. Materials and Methods: A number of forty-five different nickel titanium rotary instruments (n = 15) were used in this study. All files were used according to their manufacturers’ instructions. A specially designed, custom-made cyclic fatigue testing device was used in this study. The device had a simulated curved root canal within a stainless-steel block with a 45° angle of curvature and 5 mm radius of curvature. The time to fracture (TtF) in seconds was recorded visually using stopwatch. To characterize fracture mode, fractured fragments from each group were examined using a scanning electron microscope (SEM). The collected data were analyzed by using one-way analysis of variance (one-way ANOVA) and post-hoc Tukey multiple comparison test with a statistical significance at p < 0.05 to compare the values of time to fracture (TtF) between the tested groups. Results: When comparing the time to fracture among the tested instruments, One-way ANOVA test revealed that there was a statistically significant difference among the three NiTi instruments (p < 0.05). HyFlex EDM had the highest resistance to cyclic fatigue resistance. Scanning electron microscopy analysis showed that the fracture type of all instruments was ductile fracture. Conclusions: According to the results of this study, HyFlex EDM had the highest cyclic fatigue resistance among the Ni-Ti instruments.

Statistical analysis:
Sample size calculation:
The sample size used in this study was calculated before any work using G*Power program.
The data were analyzed using the statistical package for social science (SPSS) computer program. Using Kolmogorov–Smirnov test and the homogeneity of variances (Levene’s test), the time to fracture (TtF) values were normally distributed, so parametric tests were used to compare the groups.
Results:
The mean ± standard deviation of the cyclic fatigue test were expressed as time to fracture (TtF) in seconds, (Table). The longer time to fracture means that the tested instrument is more resistant to cyclic fatigue. One-way ANOVA test showed that there was a statistically significant difference among the three NiTi instruments ($p < 0.05$). The multiple comparison test among the three groups showed that HyFlex EDM had the highest resistance to cyclic fatigue followed by VDW.ROTATE, and TurNatomy files, respectively ($p < 0.05$).

Scanning electron microscopy:
Scanning electron microscopy analysis showed that the fracture type of all instruments was ductile fracture, (Figure 2).

<table>
<thead>
<tr>
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<th>Hyflex EDM</th>
<th>TurNatomy</th>
<th>VDW.ROTATE</th>
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<tbody>
<tr>
<td>TtF</td>
<td>636.41±107.62</td>
<td>216.36±14.33</td>
<td>421.26±46.89</td>
</tr>
</tbody>
</table>

Different letters indicate significant difference between groups

![Figure 2: Scanning electron micrographs of the fractured fragments of each file group at different magnifications; (a) Hyflex EDM, (b) TurNatomy, and (c) VDW. ROTATE](image)

Discussion:
Nickel-titanium (NiTi) endodontic instruments have become the most widely used instruments in root canal treatment (RCT). NiTi instruments are characterized by superelasticity and shape memory, but they have an unexpected fracture during instrumentation. Fracture of NiTi endodontic files during RCT can be due to cyclic fatigue and/or torsional stress or both. Cyclic fatigue occurs due to repeated compressive/tensile stresses at the point of maximum flexure. It occurs with no signs of permanent plastic deformation in NiTi instruments, so it is unexpected.
Ti endodontic instruments to decrease their cyclic fatigue fracture.  

The used Ni-Ti rotary files in this study were manufactured using different techniques. In this study, a custom-made cyclic fatigue testing device was used to compare resistance to cyclic fatigue of the file for standardization and to reduce variability. The artificial canals specifically designed to have similar size and taper of each of the used instruments. The cyclic fatigue fracture occurs due to incremental crack propagation caused by the cyclic stresses generated when the instruments are rotated in a curved root canal. So, fractured files were examined using scanning electron microscopy (SEM) to detect the mode of fracture.

In cyclic fatigue tests, the resistance of an instrument to fracture due to the accumulation of metal fatigue induced by the tension/compression cycles at the point of maximal flexure is the variable studied. This is not typical to the clinical conditions, where a fracture is caused by a combination of variables acting simultaneously at the same time. This may make it difficult to match the results of laboratory testing with a clinical condition. However, it is important to assess mechanical properties of endodontic instruments in order to present valid information for the clinician. So, this laboratory test represents a pure mechanical test to elicit only one property of the instruments (resistance to cyclic fatigue).

According to the results of the current study, there were statistically significant differences among the three evaluated NiTi instruments in terms of cyclic fatigue resistance (p < 0.05). The HyFlex EDM had the highest resistance to cyclic fatigue, followed by VDW.Rotate, and TurNatomy, respectively.

The highest cyclic fatigue resistance in the HyFlex EDM group agreed with the results of different previous studies. This may be because HyFlex EDM files are considered the first endodontic instruments manufactured with Electrical Discharge Machining technology. EDM is a non-contact thermal erosion process used to machine electrically conductive materials by means of precisely controlled electrical discharges.

According to the results in this study, the null hypothesis could be rejected. As statistically significant differences in the cyclic fatigue resistance were observed among the three evaluated files.

Methodological limitations are inherent to all in vitro studies. In the present study, it was difficult to compare the effect of a single factor on the cyclic fatigue resistance of the tested files, so trials to apply the results of this in vitro study to clinical conditions should be done with caution.

Conclusions:

HyFlex EDM had the highest cyclic fatigue resistance among the tested Ni-Ti instruments.

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References:


